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(54) **UTERINE HEMORRHAGE CONTROLLING SYSTEM AND METHOD**

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(51) **Int. Cl.**

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USPC ..... 604/93.01–95.01, 98.01–101.05, 604/118–120, 171, 176, 190, 319, 508, 509, 604/515, 533–535, 540–544, 915

See application file for complete search history.

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*Primary Examiner* — Melanie Hand

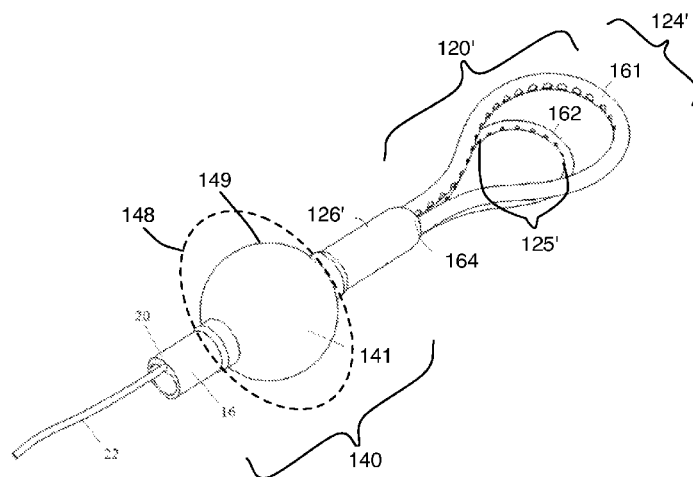
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(57) **ABSTRACT**

An embodiment of a uterine hemorrhage controlling system comprises a suction module including a suction end coupleable to a pump by a connecting tube, and a sealing module coupled to the suction module. The system may further comprise the pump and a filter coupled to the suction module. A uterine hemorrhage controlling method comprises: shielding a suction module that has been delivered into a uterus; sealing an entrance into the uterus while the suction module is situated within the uterus; applying a negative pressure within the uterus upon activation of a pump; and maintaining the negative pressure within the uterus to induce uterine contraction. The method may further comprise delivering the suction module into the uterus; transmitting bodily fluids, out of the uterus through the suction module, and filtering the bodily fluids.

**16 Claims, 10 Drawing Sheets**



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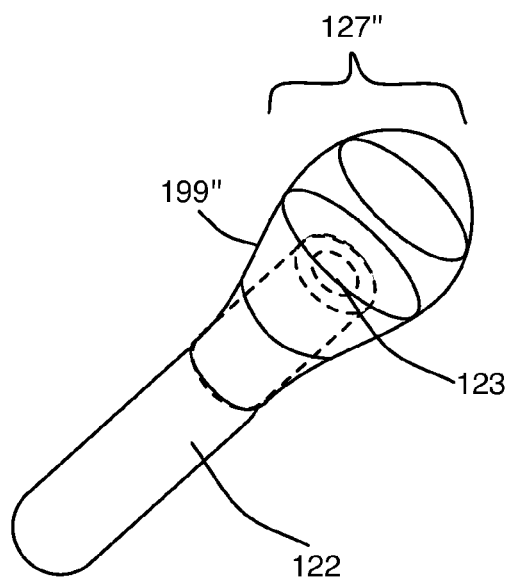
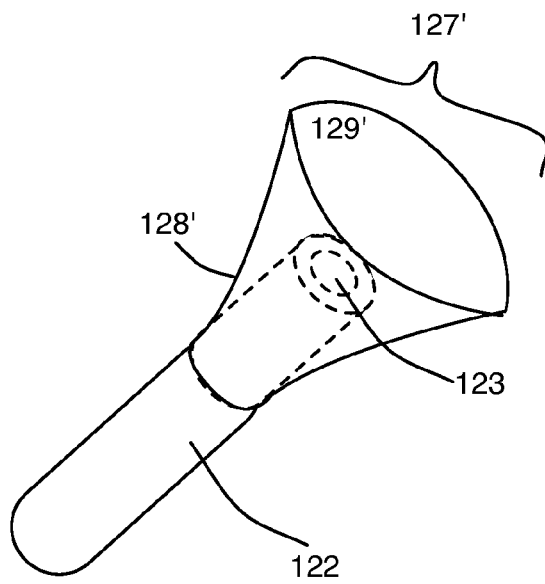
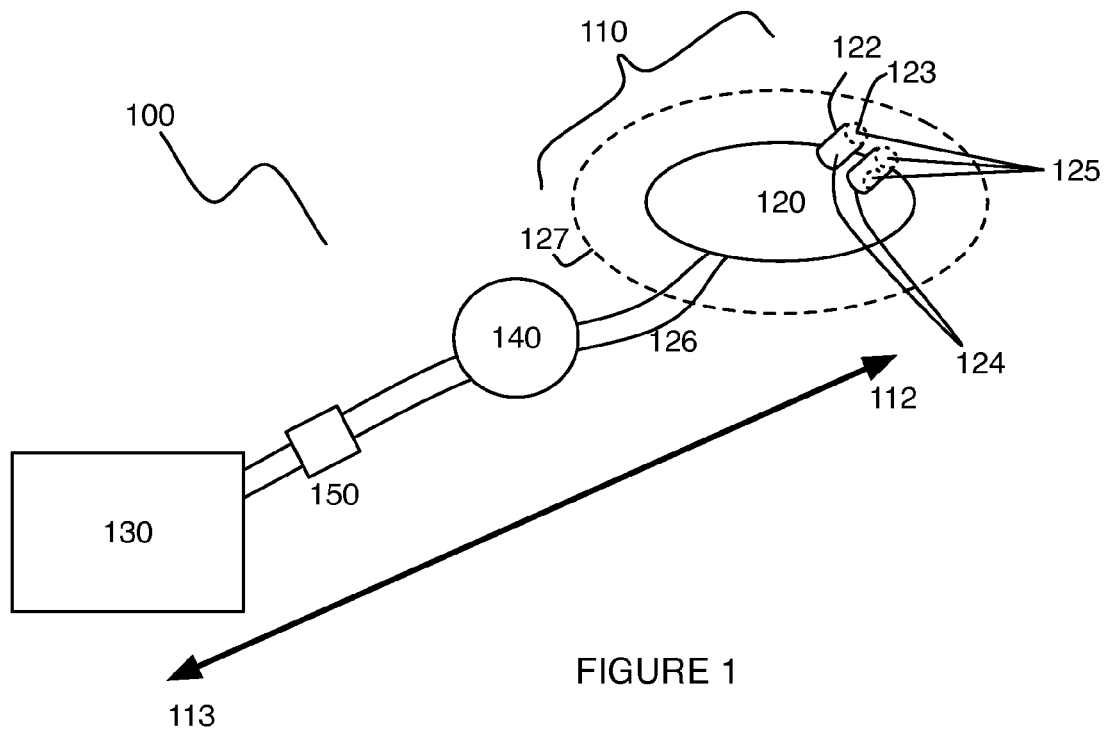
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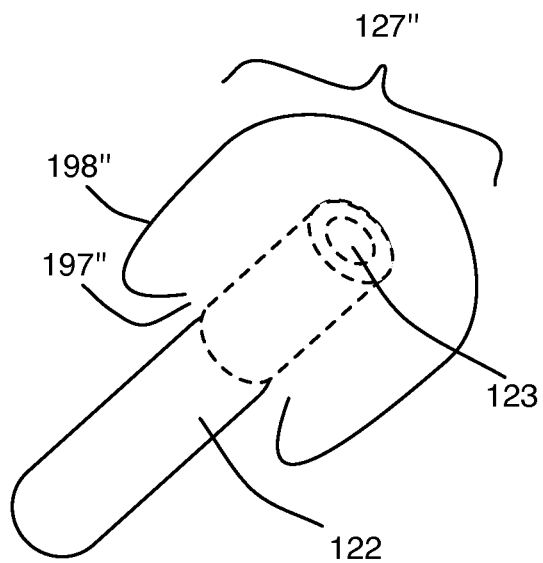


FIGURE 2C

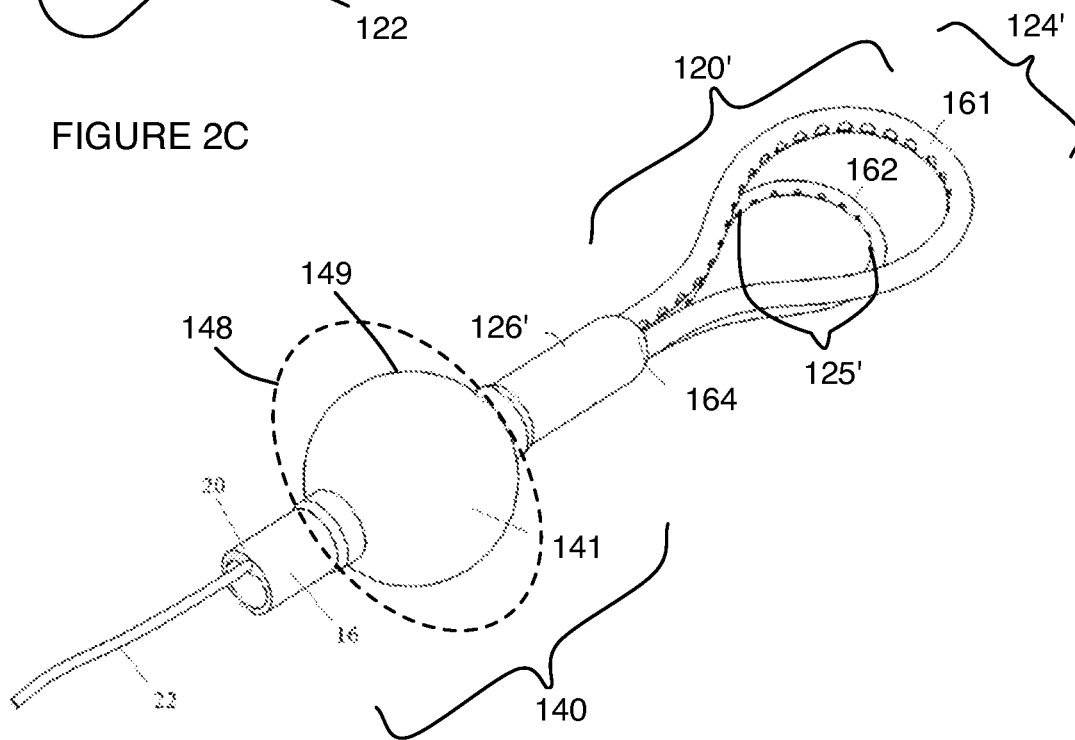


FIGURE 3A

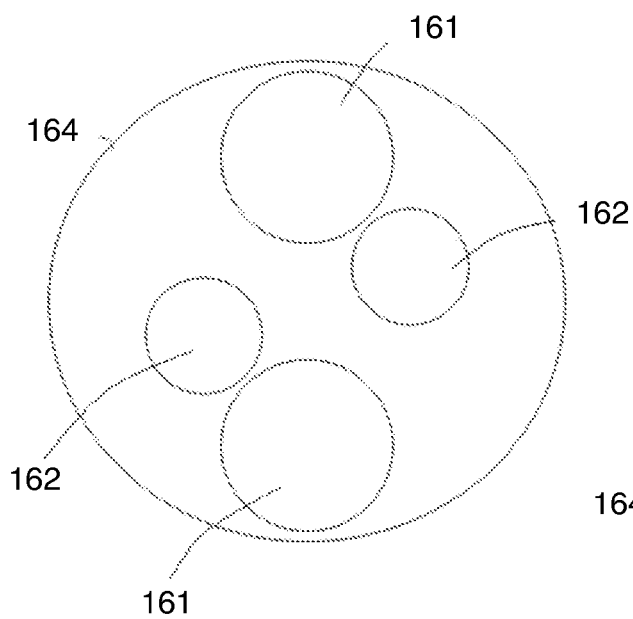


FIGURE 3B

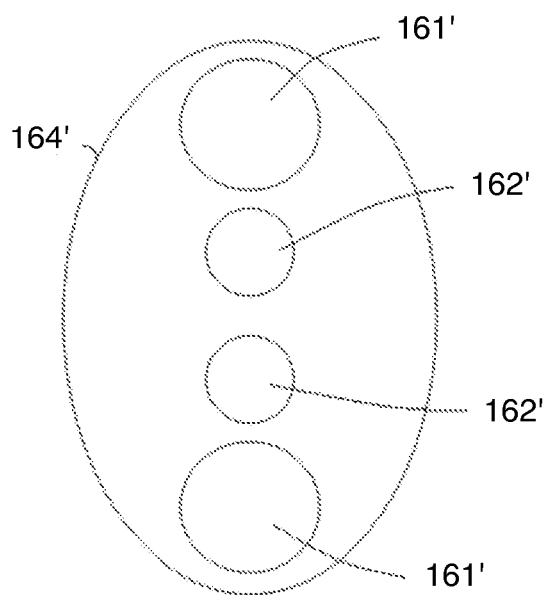


FIGURE 3C

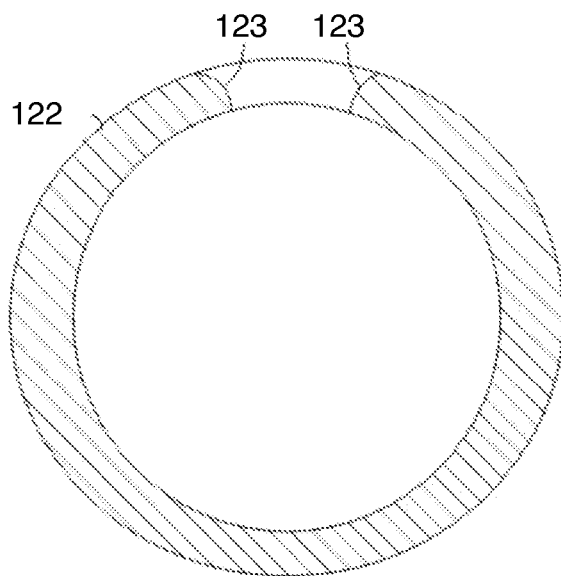
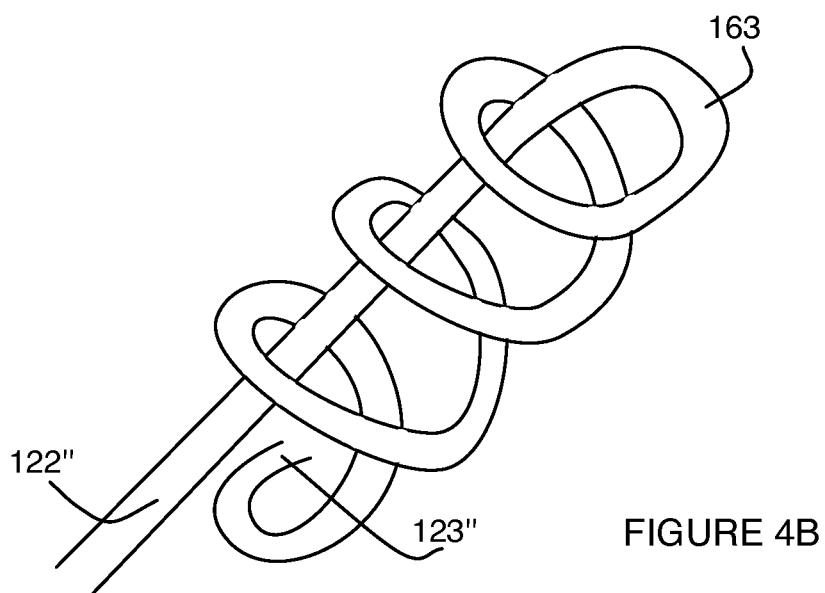
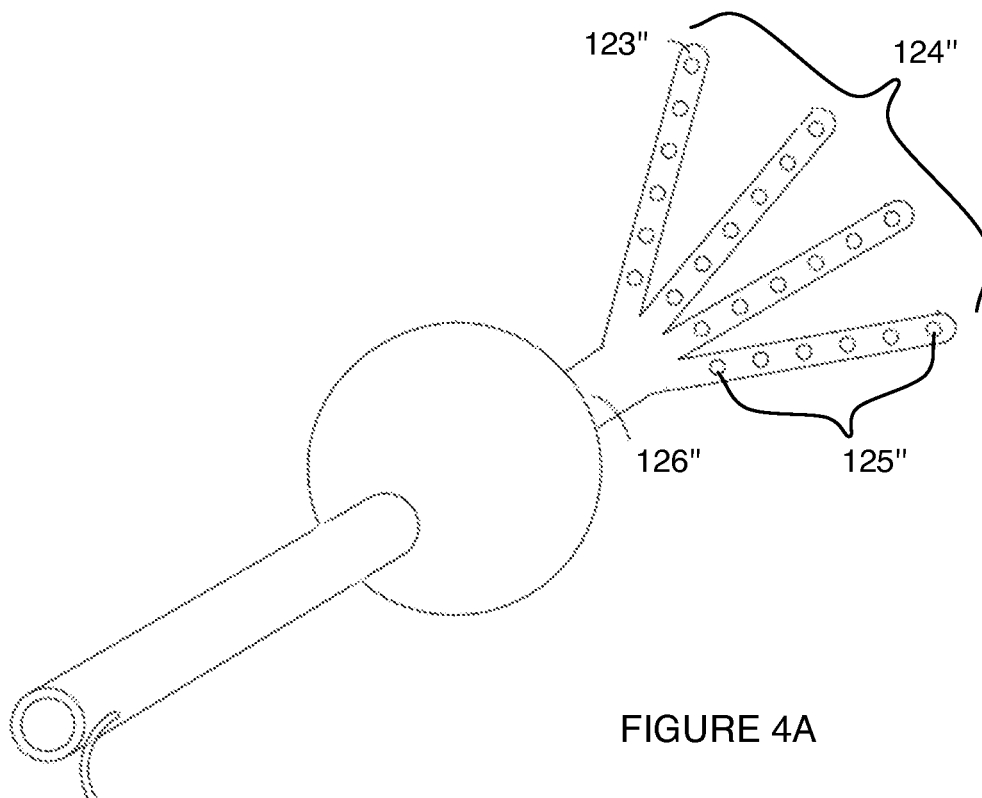


FIGURE 3D



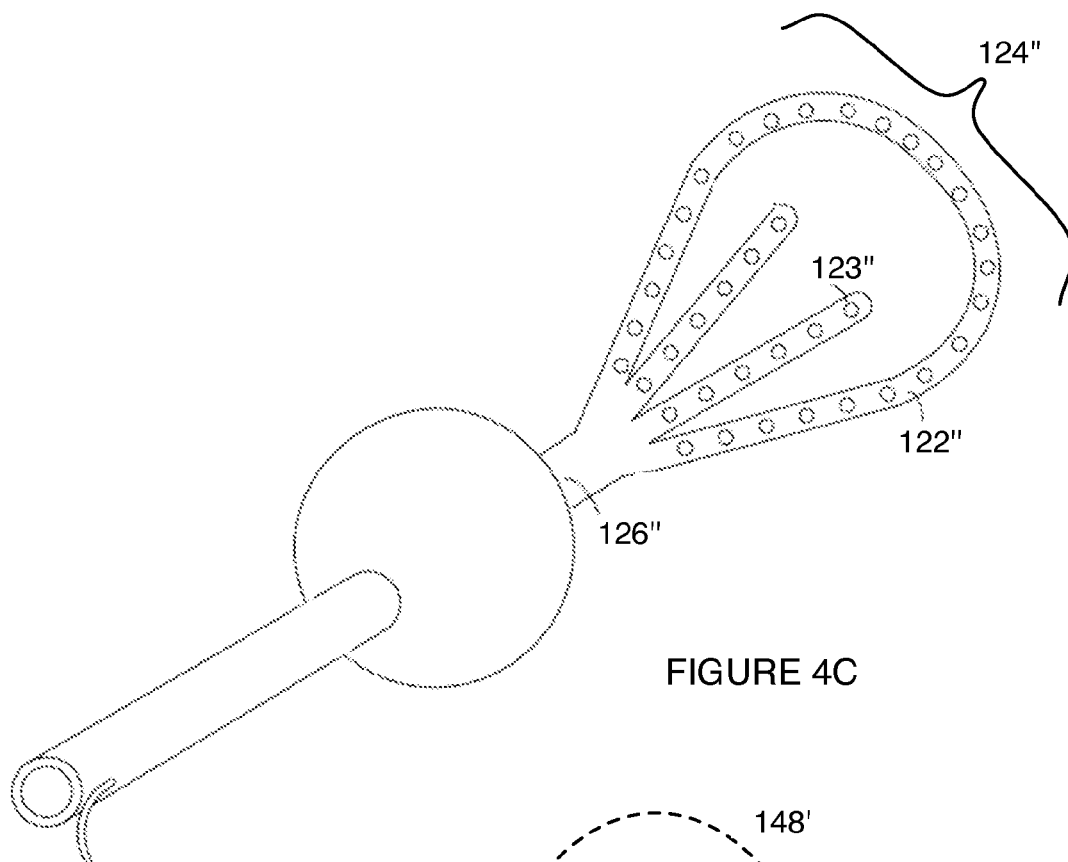


FIGURE 4C

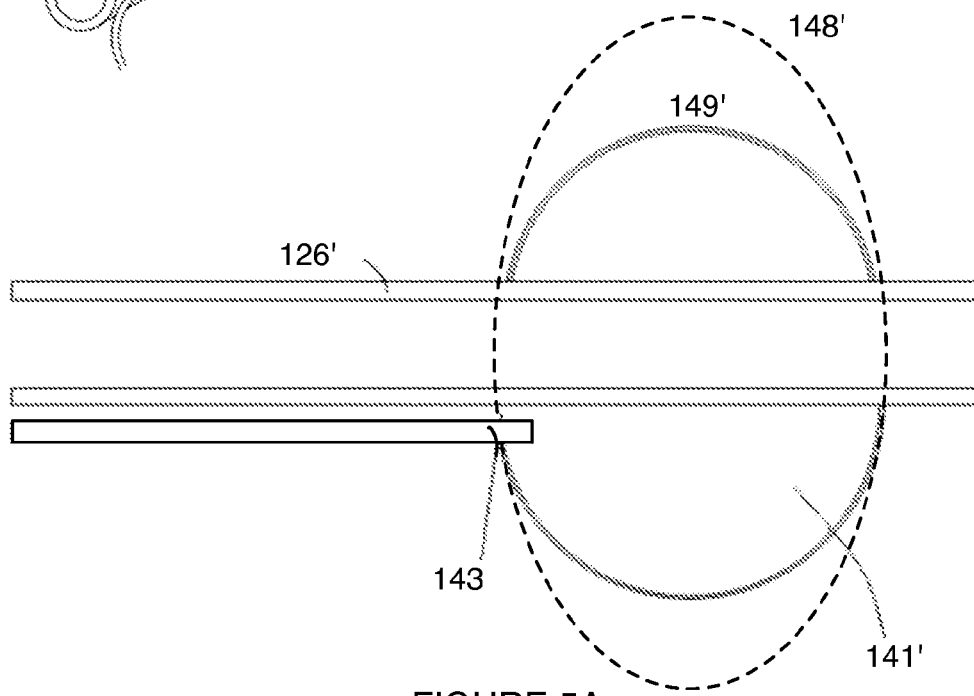
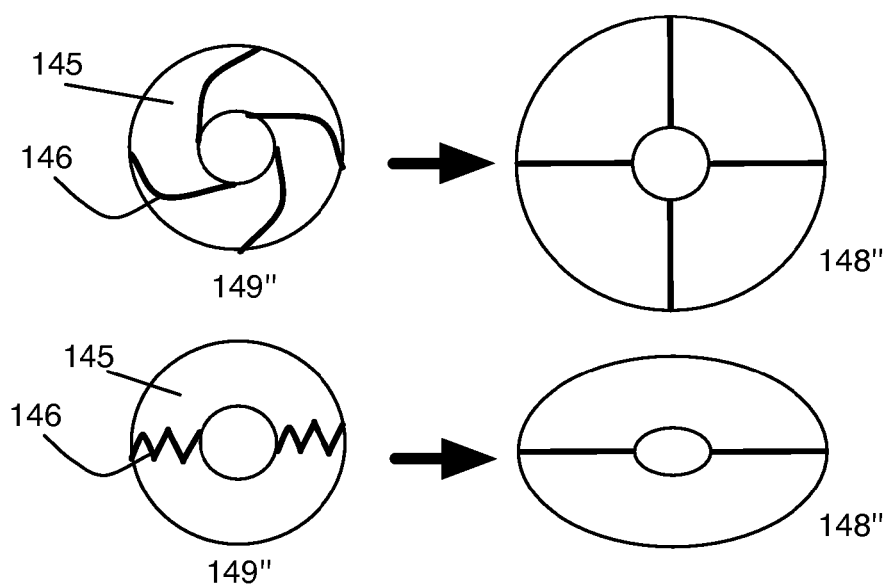
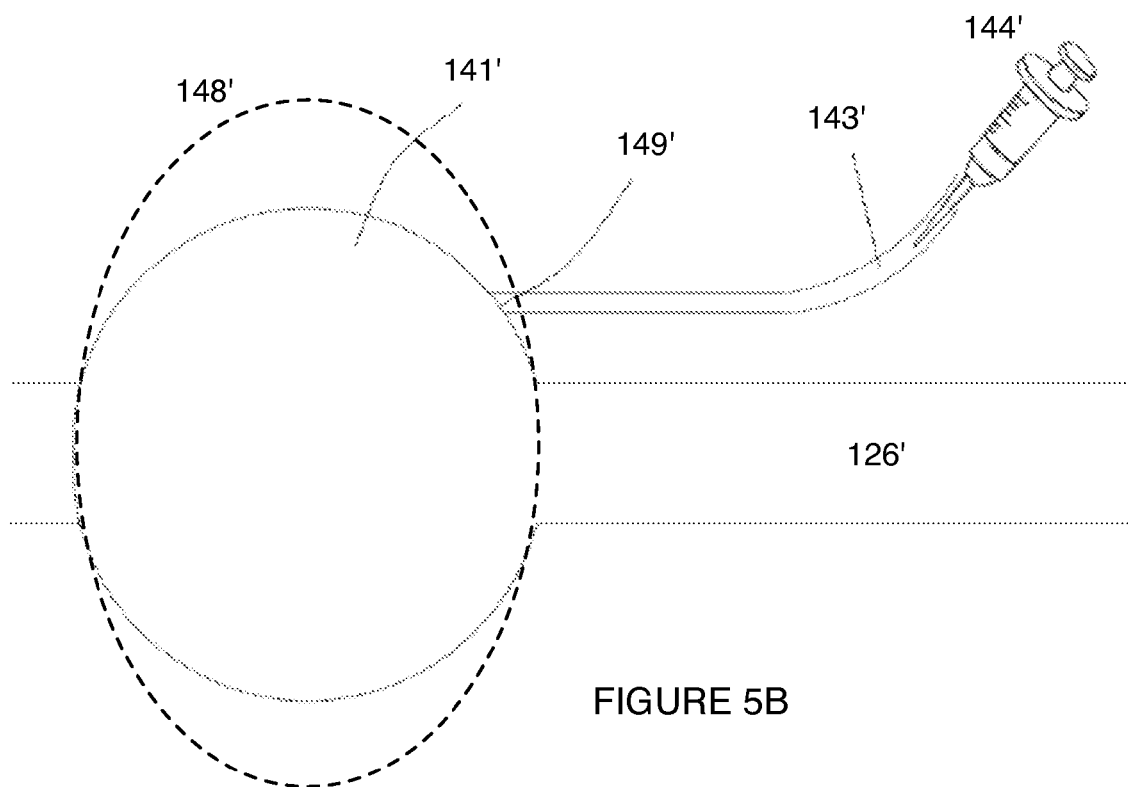


FIGURE 5A





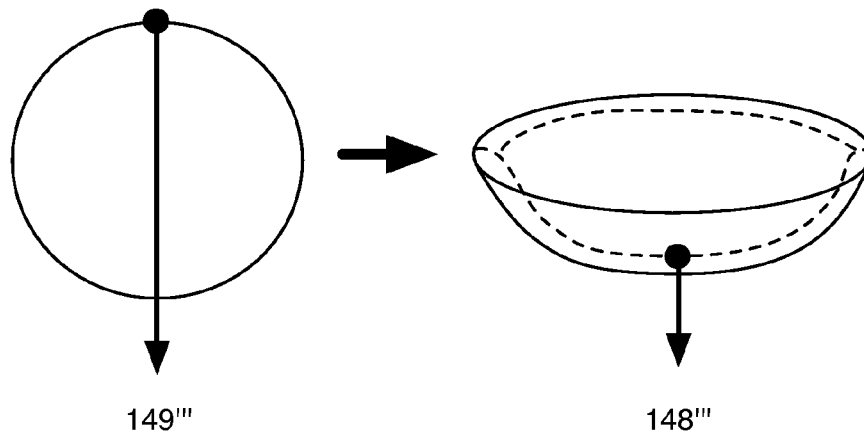


FIGURE 7

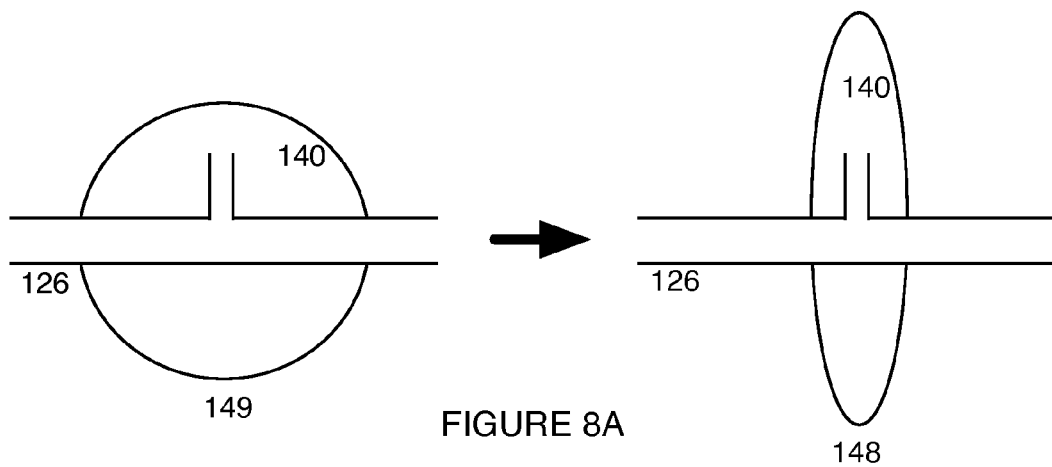


FIGURE 8A

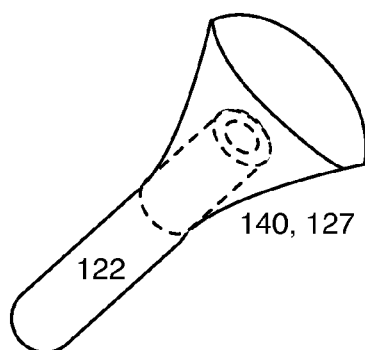


FIGURE 8B

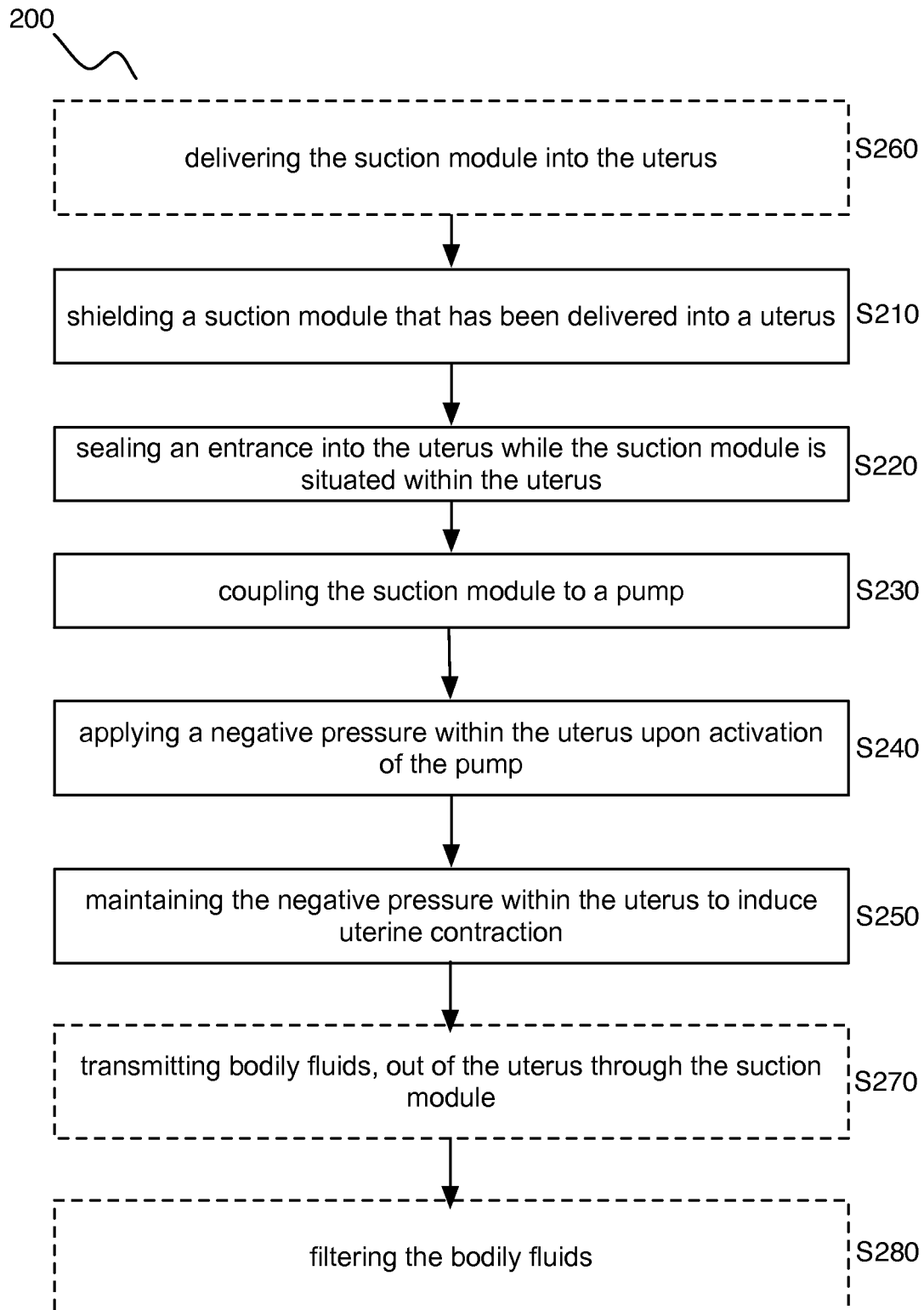
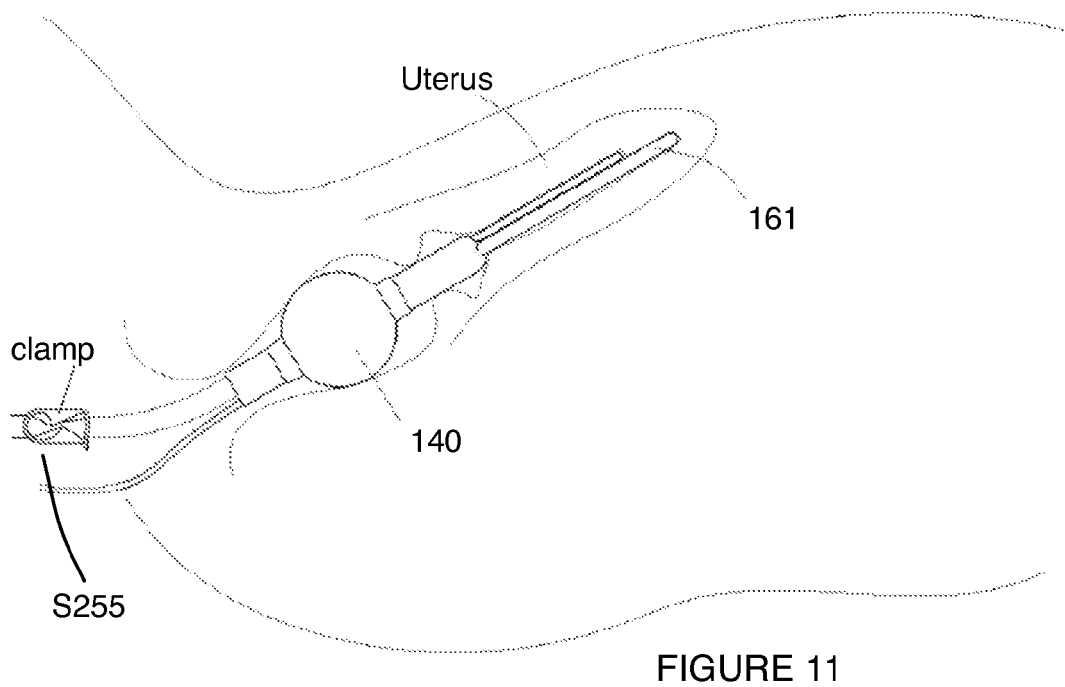
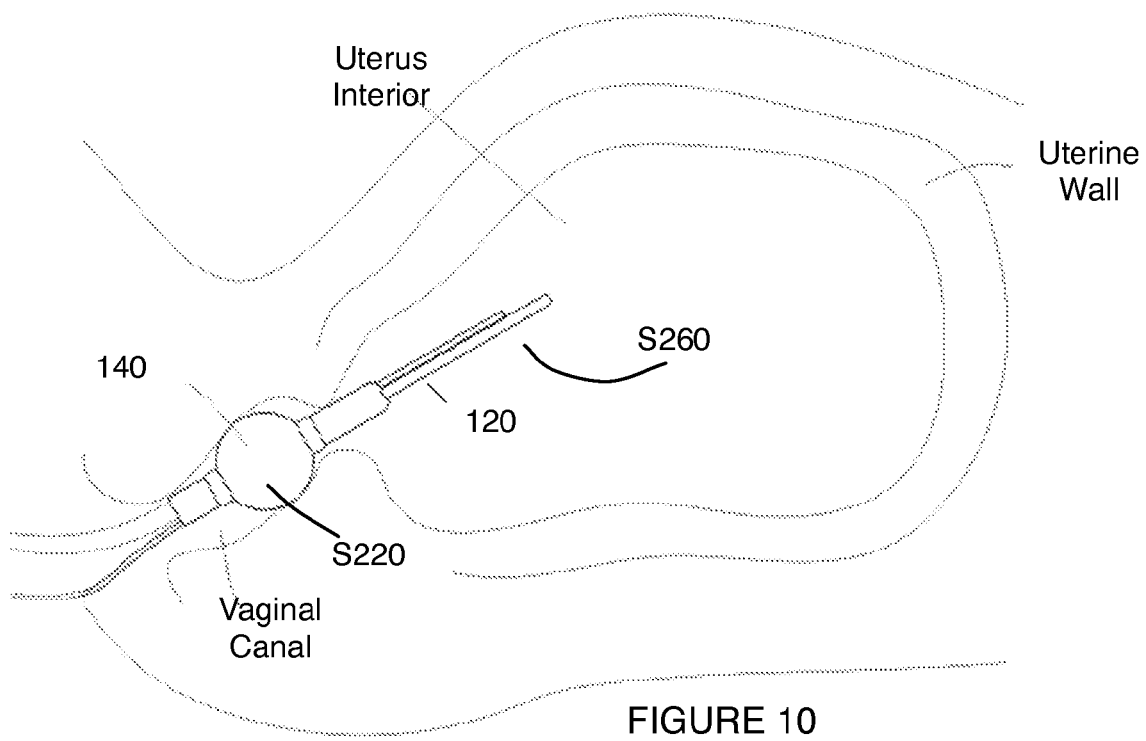
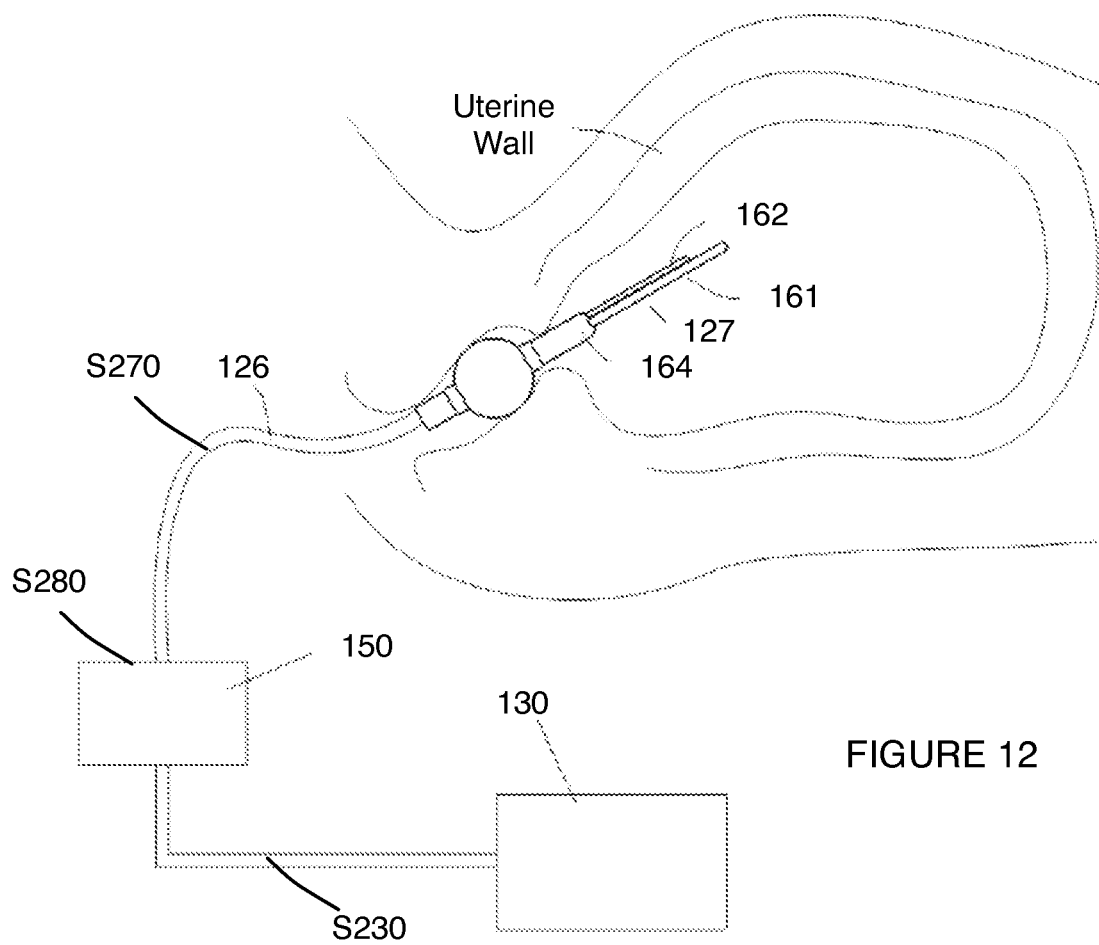


FIGURE 9





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## UTERINE HEMORRHAGE CONTROLLING SYSTEM AND METHOD

### CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation of prior application Ser. No. 13/827,579, filed 14 Mar. 2013, which is a continuation-in-part of prior application Ser. No. 13/420,871, filed 15 Mar. 2012, both of which are incorporated in their entirety by this reference.

### TECHNICAL FIELD

This invention relates generally to the medical device field, and more specifically to an improved uterine hemorrhage controlling system and method.

### BACKGROUND

Postpartum hemorrhage, defined as excessive blood loss after birth, is the leading cause of maternal death in the world, claiming the lives of over 125,000 mothers every year. Inability to control postpartum bleeding can require a woman to receive multiple blood transfusions, and in severe cases, a full hysterectomy. Accordingly, it is desirable to control such postpartum bleeding, if possible, at its onset. The cause of postpartum hemorrhage, in approximately 80% of cases, is uterine atony, which is the inability of the woman's uterus to contract after delivering the child. Risk factors for uterine atony include prolonged stage of labor, preeclampsia, and multiparity.

Postpartum hemorrhage has been traditionally treated using oxytocic agents, hormonal agents that induce muscle contraction. Unfortunately, studies have increasingly shown that oxytocic agents do not significantly reduce either the incidence of postpartum hemorrhage or the amount of blood lost. Some studies have even indicated that oxytocic agents are being overused to the point that this treatment increases the risk of uterine atony. Current medical devices and surgical procedures have also proven inadequate in reducing postpartum hemorrhage or the amount of blood lost, and/or are extremely invasive.

It has recently been discovered by the inventors that providing negative pressure within the uterus, in combination with sealing an opening to the uterus or vagina at the distal end, can rapidly induce uterine contraction to counteract uterine atony, thus reducing or entirely stopping uterine hemorrhaging. Providing negative pressure may furthermore be performed in a non-invasive (i.e., non-surgical) manner, effectively removing an inadequacy of other hemorrhage-controlling options. With the knowledge of this discovery, the inventors have created an improved uterine hemorrhage controlling system and method.

### BRIEF DESCRIPTION OF THE FIGURES

FIG. 1 depicts an embodiment of a uterine hemorrhage controlling system;

FIGS. 2A-2C depict variations of a suction tube and shield of an embodiment of a uterine hemorrhage controlling system;

FIG. 3A depicts a specific example of a uterine hemorrhage controlling system;

FIGS. 3B and 3C depict cross-sectional views of suction tube connecting joints;

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FIG. 3D shows an example of a suction tube cross section and opening;

FIGS. 4A and 4B depict examples of suction tubes that also function as shields;

FIG. 4C depicts an example of a system that combines variations of elements;

FIGS. 5A-5B depict examples of an inflatable sealing module element;

FIGS. 6 and 7 depict examples of sealing module variations;

FIGS. 8A and 8B depict examples of system elements with dual functionality;

FIG. 9 depicts an embodiment of steps of a uterine hemorrhage controlling method;

FIGS. 10-11 depict embodiments of steps of a uterine hemorrhage controlling method; and

FIG. 12 is a schematic showing an implementation of an embodiment of a uterine hemorrhage controlling method.

### DESCRIPTION OF THE PREFERRED EMBODIMENTS

The following description of preferred embodiments of the invention is not intended to limit the invention to these preferred embodiments, but rather to enable any person skilled in the art to make and use this invention.

#### 1. System

As shown in FIG. 1, an embodiment of a uterine hemorrhage controlling system **100** comprises a suction module **110** including a suction end **120** coupleable to a pump **130** by a connecting tube **126**, and a sealing module **140** coupled to the suction module **110**. The system **100** may further comprise the pump **130** and a filter **150** coupled to the suction module **110**. At least a portion of the system **100** is preferably delivered transvaginally, and facilitates contraction of the uterus to counteract uterine atony. Thus, the system **100** functions to reduce or entirely stop uterine hemorrhaging, in order to substantially reduce total blood lost from the uterus after childbirth. The system **100** may further function to reduce other issues associated with childbirth, including a need for a blood transfusion or a hysterectomy.

#### 1.1 System—Suction Module

The suction module **110** comprises a suction end **120** coupleable to a pump **130** by a connecting tube **126**, and functions to provide negative pressure within the uterus to facilitate uterine contraction. Preferably, negative pressure provided by the suction module **110** results in a uniform mechanical stimulus to the uterine wall, in order to facilitate substantially even contractile movement of tissue; however, the suction module **110** may alternatively be configured to provide a non-uniform mechanical stimulus to the uterine wall, or to decrease intra-uterine pressure and/or volume by any suitable method (e.g., mechanically, chemically, creation of a vacuum, reduction in intrauterine temperature). The suction module **110** preferably comprises a distal end **112** and a proximal end **113**, as shown in FIG. 1, wherein the distal end **112** comprises the suction end **120** and is configured to enter the uterus, and the proximal end **113** comprises the pump **130** and is configured to remain external to the uterus. However, both the distal end **112** and the proximal end **113** may be configured to enter the uterus. Preferably, the distal end **112** and the proximal end **113** are coupled by the connecting tube **126** (e.g., by a conduit, tubing, chamber), and may be further configured to be reversibly coupled in variations wherein at least one of the distal end **112** and the proximal end **113** is configured to be disposable. In some variations, the suction module **110** may further comprise a pressure sensor and/or a

controller, which functions to facilitate measurement of a pressure provided by the pump **130** and/or a pressure within the uterus, and also to controllably adjust a negative pressure provided within the uterus.

The suction end **120** is configured to be transvaginally delivered, and functions to transmit a negative pressure provided by the pump **130** to the interior of the uterus, while preventing tissue or any other substance within the uterus from obstructing the suction end **120**. The suction end **120** is preferably flexible, and may be further configured to be deformed into one or more configurations. Flexibility in the suction end **120** may further function to facilitate conformation of the suction end **120** to the intra-uterine anatomy of the patient. Variations of a flexible suction end **120** may be configured to be reversibly or irreversibly deformable. Alternatively, the suction end **120** may be rigid and substantially non-deformable, or may be configured to be rigid in one environment, and transition to a flexible state in another environment. Preferably, the suction end **120** is composed or partially composed of a medical-grade material (e.g., polyethylene, polypropylene, stainless steel, cobalt chrome, ceramic), such that the suction end **120** does not induce an adverse reaction after being inserted into a uterus of the patient. The suction end **120** may further be configured to prevent or counteract an inflammatory or biorejection response by processing the suction end material with anti-inflammatory and/or anti-biorejection agents (e.g., steroidal or non-steroidal anti-inflammatory agents). However, the suction end **120** may alternatively be composed of any suitable material that does not prevent the suction end **120** from transmitting a negative pressure to the interior of the uterus.

Preferably, at least a portion of the suction end **120** is configured to be disposable, such that the suction module **110** is modular and comprises components that may be removably attached together. In variations of a modular suction module **110**, attachment locations between various components are preferably configured to provide hermetic seals, in order to prevent fluid and/or air leakage along the suction module **110**. At least a portion of the suction end **120** may alternatively be configured to be reusable, and may or may not comprise hermetic seals at locations of coupling. In variations wherein a portion of the suction end **120** is configured to be reusable, the suction end **120** preferably comprises a material that may be sterilized without compromising the function of the suction end **120**. The material may be configured to be sterilized by dry heat sterilization, moist heat sterilization, ethylene oxide sterilization, radiation (e.g., ultraviolet, gamma, electron beam), liquid chemical sterilization, or any other suitable sterilization method. In a specific example, the material is configured to be sterilized according to the U.S. Food and Drug Administration 510(k) Sterility Review Guidance K90-1.

The suction end **120** of the preferred embodiments includes a suction tube **122** and a shield **127** coupled to a distal portion of the suction tube **122** configured to enter the uterus. The suction end **120** may, however, omit the shield **127** in other embodiments. The suction tube **122** comprises an opening **123** fluidically coupled to a lumen of the connecting tube **126**, which functions to allow a negative pressure to be transmitted from the pump **130**, through the connecting tube **126**, to the uterus. Preferably, the suction tube **122** is flexible, as described above; however, the suction tube **122** may alternatively be non-flexible or undergo a transition from a flexible state to a rigid state in different environments. Additionally, the suction tube **122** may be one of a set of suction tubes **124** coupled to the pump **130**, such that the suction end **120** has an inherent redundancy of suction tubes configured to allow a

negative pressure to be transmitted into the uterus. Furthermore, the suction tube(s) may comprise a set of openings **125**, the suction tube(s) may be configured to have a curved portion, and/or the suction tube(s) may be configured to have a non-curved portion. Additionally, the suction tube(s) **122** may have any suitable length, diameter, or cross-sectional shape (e.g., uniform, non-uniform) configured to facilitate provision of a negative pressure within the uterus.

In a first variation, the suction end **120** comprises a single suction tube **122** with a single opening **123**. In an example of the first variation, a lumen of the single suction tube **122** terminates in the single opening **123** at a distal end of the suction tube **122**, and in another example of the first variation, the single opening **123** is located at any point along the length of the suction tube **122**. In a second variation, the suction end **120** comprises a single suction tube **122** with a set of openings **125**. In a third variation, the suction end **120** comprises a set of suction tubes **124** with a set of openings **125**. In other variations, the suction end **120** may have any suitable combination of the above variations, or any suitable configuration to facilitate provision of a negative pressure within the uterus.

The shield **127** functions to provide a barrier, in order to prevent obstruction of the opening(s) of the suction tube **122** or set of suction tubes **124** by uterine tissue or any other substance within the uterus. The shield **127** is preferably coupled to a distal portion of the suction tube **122** or set of suction tubes **124** configured to enter the uterus, but may be coupled to any suitable portion of the suction module **110** or suction tube **122** to prevent obstruction. The shield **127** is preferably composed of a medical-grade material, such as a medical-grade metal or polymer, but may be composed of any suitable material to prevent obstruction of the opening(s). Additionally, the shield **127** may be rigid or flexible.

In a first variation, the shield **127'** is configured to couple to a portion of a suction tube **122** and diverge outward from the suction tube **122** at least at a location of an opening **123** to form a perimeter, such that uterine tissue or other tissue is prevented from impinging upon the opening **123**. In an example of the first variation, the shield **127'** comprises a conical or pyramidal surface **128'** that flanks a suction tube **122** and that has an open mouth **129'** that extends beyond a distal end of the suction tube **122**, as shown in FIG. 2A. In a second variation, the shield **127''** may partially encapsulate an opening **123** (e.g., by a cage or a frame) to prevent obstruction of the opening **123**. In an example of the second variation, as shown in FIG. 2B, the shield **127''** may form a bulbous cage **199''** about an opening **123**. The dimensions of the bulbous cage are preferably smaller than the atonic uterus, such that sufficient contraction may be enabled, and smaller than the vagina opening, such that correct position may be reached. In another example of the second variation, as shown in FIG. 2C, the shield **127'''** may form a capsule **198'''** about an opening, wherein the body of the capsule **198'''** prevents obstruction of an opening **123** of the suction tube **122**, and wherein the capsule has an hole **197'''** configured to allow the suction tube **122** to facilitate creating of a negative pressure within the uterus. The shield **127** may, however, comprise any suitable geometry and/or configuration to prevent obstruction of the opening(s) of the suction tube **122** or set of suction tubes **124**.

In alternative variations, the suction tube **122** or the set of suction tubes **124** may be configured to also function as a shield **127** (or to be physically coextensive with the shield). In these alternative variations, the suction tube **122** or the set of suction tubes **124** thus functions to simultaneously allow a negative pressure to be applied within the uterus, while preventing obstruction of suction tube opening(s). This dual-functionality may be enabled by strategic placement of the

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opening(s) **123**, **125** of the suction tube(s) **122**, **124**, and/or by geometrically configuring the suction tube(s) to prevent obstruction of an opening or openings.

In a first variation of an embodiment wherein the suction tube(s) function as a shield, the suction end **120'** may comprise a set of curved suction tubes **124'** connected to a connecting tube **126** coupleable to the pump **130**, as shown in FIG. 3A. In an example of the first variation, the set of curved suction tubes **124'** may comprise a first suction tube **161** and a second suction tube **162** that are arranged in loops that extend different distances. As shown in the cross sections of FIGS. 3B and 3C, the first suction tube **161** and the second suction tube **162** may be coupled to the connecting tube **126** by a joint **164**. In the example, the first suction tube **161** may have a longer length and extend in a wider loop from the distal end **112** of the suction module, and the second suction tube **162** may have a shorter length and be configured in a loop that is within the loop created by the first suction tube **161**. The first suction tube **161** and the second suction tube **162** in the example may have identical or non-identical cross sections (e.g., dimensions, geometry, lumen configurations), a maximum cross sectional dimension between 25 mm and 125 mm, and substantially smooth surfaces to prevent abrasion within the vagina/uterus. The set of curved suction tubes **124'** in the first example is composed of a medical-grade material that is flexible enough to conform to intra-uterine anatomy, but rigid enough to maintain fixed angles at the point of connection between the set of curved suction tubes **124'** and the connecting tube **126**. The medical-grade material in the example has a Shore A hardness value between 50 and 90. In the example of the first variation, the set of curved suction tubes **124'** comprises up to eight suction tubes **122'**.

In the example of the first variation, each suction tube **122'** in the set of curved suction tubes **124'** comprises a lumen that is coupled, by the connecting tube **126'**, to the pump **130**, and also connected to a set of openings **125'**. A negative pressure provided by the pump **130** therefore facilitates uterine contraction and allows intra-uterine fluids to flow through a set of openings **125'** into the lumen of a suction tube **122'**. The set of openings **125'** in the example are oriented to open along a medial surface of a suction tube **161**, **162** to prevent uterine tissue or other tissue from obstructing the set of openings **125'**. The set of openings **125'** in the example comprises openings **123'** that are between 1 and 6 mm in diameter, and are also substantially smooth and rounded, as shown in the cross-section of FIG. 3D, to prevent damage to the uterus or other tissues.

In a second variation of an embodiment wherein the suction tube(s) function as a shield **127**, the set of suction tubes **124"** branch from the connecting tube **126"**, and at least one of the set of suction tubes **124"** comprises a set of openings **125"** along a medial surface of a suction tube of the set of suction tubes **124"**. The branched configuration functions to prevent tissue from obstructing the medially oriented openings. In an example of the second variation, as shown in FIG. 4A, the set of suction tubes **124"** comprises openings **123"** that are between 1 and 6 mm in diameter, and up to 16 suction tubes with smooth and/or rounded edges to prevent damage to the uterus or other tissues.

In a third variation of an embodiment wherein the suction tube(s) function as a shield **127**, a suction tube **122'''** or a set of suction tubes **124'''** may comprise a turnabout portion **163** configured to prevent an opening from being obstructed. In an example of the third variation, a turnabout portion **163** of a suction tube **122'''** may be configured to wrap around itself along a portion of the length of the suction tube **122'''**, as shown in FIG. 4B. In another example, a set of suction tubes

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**124'''** may comprise a suction tube **122'''** with a turnabout portion **163** configured to partially wrap around a length of the set of suction tubes **124'''**. Alternatively, the turnabout portion **163** may not be configured to partially wrap about a suction tube **122'''**, but may still provide a shield **127** by providing a barrier to prevent obstruction of an opening.

Other variations of the suction tube(s) **122**, **124**, shield **127**, and/or dual-functioning suction tube(s) may comprise any suitable combination of the above variations, an example of which is shown in FIG. 4C.

## 1.2 System—Sealing Module

The sealing module **140**, which is preferably proximal to the suction end **120** and comprises a deformable seal **142**, functions to provide a seal such that negative pressure may be maintained within the uterus to facilitate contraction of the uterus. The sealing module **140** may be configured to provide a seal at any point from the vulva, the cervix, or any point within the uterus, but preferably provides a seal at a point along the vagina distal to the uterus. The sealing module **140** may also be configured to be deformable, such that the sealing module **140** has more than one configuration; however, the sealing module **140** may be configured to be substantially non-deformable, such that the sealing module **140** only has a single configuration. Preferably, a complete seal (e.g., airtight/hermetic) is provided by the sealing module **140**, such that a negative pressure is maintained within the uterus even after the pump **130** is deactivated; however, a non-complete seal may be provided by the sealing module **140**, such that an adequate negative pressure is transmitted to the uterus while the pump **130** is activated, but the negative pressure is not maintained after the pump **130** is deactivated. Furthermore, at least a portion of the sealing module **140** may be configured to be disposable, and at least a portion of the sealing module **140** may be configured to be reusable.

In a first variation, the sealing module **140** is configured to provide a seal within the vaginal canal and/or at the cervix. In the first variation, the sealing module **140** may comprise a seal **141** that is configured to deform, reversibly or irreversibly, into at least two configurations. A first configuration **148** preferably activates the seal, and a second configuration **149** preferably deactivates the seal. Producing the first configuration may involve an expansion (e.g., radial, axial, uniform, non-uniform, isotropic, non-isotropic) of the seal **141**, and producing the second configuration **149** may involve a contraction (e.g., radial, axial, uniform, non-uniform, isotropic, non-isotropic) of the seal **141**. Producing the first configuration **148** may alternatively involve releasing a constrained seal **141**, and producing the second configuration may involve constraining a released seal **141**. However, the seal **141** in the first variation may be a non-deformable seal that has a single configuration.

In a first specific example of the first variation, as shown in FIGS. 3A and 5A, the seal **141'** is an inflatable balloon configured to deform into an expanded configuration **148'** and a contracted configuration **149'**. Upon delivering the suction end **120** transvaginally, the seal **141'** in the first specific example is configured to be situated, in the contracted configuration **149'**, within the vaginal canal. The seal **141'** may then be expanded to produce an expanded configuration **148'** that seals the vagina in order to facilitate maintenance of a negative pressure within the uterus. In the first specific example, the seal may be expanded isotropically by delivering a fluid (e.g., saline or water) or a gas (e.g., air, nitrogen) to the interior of the inflatable balloon from a source external to the seal through an opening into the inflatable balloon. The expanded configuration **148'** of the seal in the first specific example substantially fills the entire cross section of the

entrance of a woman's postpartum uterus (e.g., the balloon inflates to have a volumetric capacity up to 300 milliliters, the balloon inflates to have a volumetric capacity greater than 300 milliliters), and has a diameter between 5 and 14 cm (with a mean diameter of approximately 10 cm). The inflatable balloon in the first specific example can also withstand an internal pressure of at least 5 psi, and can be reversed to a contracted configuration **148'** upon delivery of the fluid or gas from the interior of the inflatable balloon.

In the first specific example, as shown in FIGS. **5A** and **5B**, the inflatable balloon surrounds the connecting tube **126** coupled to the suction end **120**, such that the connecting tube **126** is isolated from and passes entirely through the inflatable balloon. A separate delivery conduit **143**, coupleable to a fluid or gas source **144**, then transfers a gas or fluid through an opening into the inflatable balloon. The delivery conduit in the first specific example is composed of silicon, but may alternatively be composed of any other suitable material (e.g., rubber, plastic, silicone, silastic, plastic, polyethylene, polyurethane).

In the first specific example, the seal **141** may alternatively be expanded by producing a chemical reaction (e.g., mixture of an acid with a base, or any reaction that produces a volumetric expansion) within the interior of the sealing balloon. For instance, an acidic solution may be isolated from a chemical base within the sealing balloon, and upon mixture of the acidic solution with the chemical base, a resulting chemical reaction may produce a controlled, volumetric expansion of the sealing balloon by the production of a gas within the sealing balloon.

In a second specific example of the first variation, the seal **141'** comprises a membrane **145** and at least one deformable member **146**, and is configured to expand radially outward into a first configuration **148'** and to contract radially inward into a second configuration **149'** upon manipulation of the deformable member **146**. Upon delivering the suction end **120** transvaginally, the seal **141'** in the second specific example is configured to be situated in the second configuration **149'**, within the vaginal canal. As shown in FIG. **6**, the deformable member **146** may be configured to produce an expansion in one, two, or three dimensions (e.g., upon release of a compressed elastically deformable member), and to produce a contraction in one, two, or three dimensions (e.g., upon compression of an elastically deformable member). Alternatively, the deformable member **146** may be a brace attached to the membrane **145** that can outwardly push the membrane **145** into the first configuration **148'** and can inwardly pull the membrane **145** into the second configuration **148'**. In another alternative version of the second example, the deformable member **146** may be a shape-memory material, such as nitinol, that outwardly pushes the membrane **145** into a first configuration **148'** in one environment (e.g., within the body), and inwardly pulls the membrane **145** into a second configuration **148'** in another environment (e.g., outside of the body).

In a third specific example of the first variation, the seal **141'''** is configured to take on a first geometric configuration **148'''** upon an axial deformation of the seal **141'''** and to take on a second geometric configuration **149'''** in response to a reverse deformation of the seal **141'''**. Upon delivering the suction end **120** transvaginally, the seal **141'''** in the third specific example is configured to be situated, in the first geometric configuration **149'''**, within the vaginal canal. In the third specific example, the seal **141'''** may be structurally configured with a wall that produces a sealing configuration **148'''** upon axial deformation and to produce a non-sealing configuration **149'''** upon removal of the axial deformation, as

shown in FIG. **7**. The wall may further comprise ridges or other structures that control deformation into the sealing configuration **148'''**. Alternatively, the seal **141'''** may be composed of an incompressible, deformable material, such that axial deformation produces an outward expansion to form the seal, and removal of the axial deformation results in an inward contraction that reverses the seal. In another alternative version of the third example, the seal **141'''** may comprise a shape-memory material, such as nitinol, that forms a sealing configuration **148'''** in one environment (e.g., within the body), and forms a non-sealing configuration **149'''** in another environment (e.g., outside of the body).

In a fourth specific example of the first variation, the seal **141''''** comprises a porous material (e.g., sponge, polymer hydrogel) that is configured to deform into an expanded configuration **148''''** upon absorption of a fluid, and to be in a non-expanded configuration **149''''** in the absence of a fluid. The porous material may be inserted into the body in a non-expanded configuration **1497** and may form the expanded configuration **148''''** of the seal upon absorption of blood, uterine fluids, or any other fluids. The seal **141''''** of the fourth example may thus further function to control blood loss/hemorrhaging by absorbing blood.

In a second variation, the sealing module **140** is configured to provide a seal at the vulva in an extracorporeal manner. In an example of the second variation, the sealing module **140** comprises a membrane **146** configured to seal the entrance to the vagina external to the body. The membrane **146** has an area larger than the entrance to the vagina, such that an adequate seal may be formed. The sealing module **140** may further comprise a sealant **147** (e.g., gel or lubricant) placed between the membrane **146** and the body, such that a hermetic and airtight seal is formed at the vulva. In this manner, the entrance to the vagina is substantially sealed to allow a negative pressure to be provided within the uterus.

In other variations, the sealing module **140** may only have a single configuration **148** configured to produce a seal upon insertion into the body. Prior to insertion, the vagina or vaginal canal may be manually expanded (e.g., with a speculum operated by a health care provider), the sealing module **140** may be inserted (with the suction end **120** already inserted), and the vagina or vaginal canal may then be released to form a seal about the sealing module **140**. In an example, the sealing module **140** is a substantially rigid structure that has a cross section larger than the cross section of the vaginal canal, such that the vaginal canal seals around the rigid structure.

Additional variations of the sealing module **140** may comprise any suitable combination of the above variations, or combination of any of the above variations with any other suitable sealing element. Furthermore, in other variations, as shown in FIG. **8A**, the connecting tube **126** of the suction module may be coupled to the sealing module **140**, such that a negative pressure provided by the suction module **110** contracts the uterus and produces a sealing configuration by the sealing module **140**. Additionally, other variations may comprise a sealing module **140** that functions as a shield **127** (or is physically coextensive with a shield), an example of which is shown in FIG. **8B**. Again, the sealing module may comprise any suitable combination or configuration of elements as described.

### 1.3 System—Other Elements

As shown in FIG. **1**, the system **100** may further comprise a pump **130**, which functions to generate the negative pressure in order to contract the uterus. The pump may comprise a clinical (e.g., hospital) suction line, vacuum device, or any appropriate pump (e.g., syringe pump, peristaltic pump) that can produce an adequate negative pressure to contract the



uterus. In a specific example, the pump generates a negative pressure within the uterus of up to 3 psi. In one variation, the connecting tube **126** of the suction module **110** is configured to couple to the pump **130** in a reversible manner. However, the connecting tube **126** may also terminate in a pump element in a non-reversible manner, such that the pump **130** is integrated with the system **100**. In an example, the pump element is a hollow chamber with a naturally expanded configuration. The pump element in the example may be constrained in a depressed state prior to delivering the suction end **120** into the uterus, after which the pump element is released to expand freely. Expansion of the pump element thus generates the negative pressure required to facilitate contraction of the atonic uterus.

Also shown in FIG. **1**, the system **100** may further comprise a filter **150**, which functions to filter fluids and other substances that have entered the connecting tube **126**. The filter is preferably distal to the pump **130** and proximal to the suction end **120**, such that any substance that enters the suction end **120** is filtered prior to reaching the pump **130**. Alternatively or additionally, the opening(s) of the suction end **120** may comprise filters that function to prefilter substances that enter the suction end **120**. The filter **150** preferably comprises a membrane with pores that prevent passage of unwanted substances into the pump.

As a person skilled in the art will recognize from the previous detailed description and from the figures and claims, modifications and changes can be made to the preferred embodiments of the system without departing from the scope of this invention.

## 2. Method

As shown in FIG. **9**, a uterine hemorrhage controlling method **200** comprises: shielding a suction module that has been delivered into a uterus **S210**, sealing an entrance into the uterus while the suction module is situated within the uterus **S220**; coupling the suction module to a pump **S230**; applying a negative pressure within the uterus upon activation of the pump **S240**; and maintaining the negative pressure within the uterus to induce uterine contraction **S250**. The method **200** may further comprise delivering the suction module into the uterus **S260**; transmitting bodily fluids out of the uterus through the suction module **S270**, and filtering the bodily fluids **S280**. The method **200** thus functions to reduce or entirely stop uterine hemorrhaging, in order to substantially reduce total blood lost from the uterus after childbirth. The method **200** may further function to reduce other issues associated with childbirth, including a need for a blood transfusion or a hysterectomy. Furthermore, because the method **200** is performed transvaginally, a patient may remain conscious while the method **200** is performed. The method **200** is preferably performed by the system **100** described above or using the system **100** described above; however, the method **200** may be performed by or using any other suitable system.

Step **S210** recites shielding a suction module that has been delivered into a uterus, and functions to prevent obstruction of a suction module opening, such that a negative pressure may be applied to the interior of the uterus. Preferably, Step **S210** is performed using any suitable variation of the shield and/or dual-functioning suction end described above. For example, Step **S210** may be implemented using a shield to shield the suction tube, or may be implemented using a suction tube with medially oriented openings, such that the suction tube dually functions as a shield. However, Step **S210** may be formed using any suitable element or method to prevent uterine tissue or any other tissue from blocking an opening of the suction module.

Step **S220** recites sealing an entrance into the uterus while the suction module is situated within the uterus, and functions to enable maintenance of a negative pressure within the uterus. Preferably, Step **S220** is performed using any suitable variation of the sealing module described above, an example of which is shown in FIG. **10**; however, Step **S220** may be formed using any suitable element or method configured to seal an entrance into the uterus. In a first example, Step **S220** comprises expanding an inflatable balloon seal (e.g., by delivering fluid or gas into the balloon) at the entrance to the uterus. In the first example, the inflatable balloon may be inflated near the distal end of the vagina to a pressure of up to 5 psi. In a second example, **S220** comprises producing a radial expansion of a membrane seal. In a third example, **S220** comprises axially deforming a seal to transform the seal into a sealing configuration. In a fourth example, **S220** comprises applying a sealant external to the vaginal canal and placing a sealing membrane at the entrance to the vaginal canal to create a seal. In a fifth example, **S220** comprises manually expanding the vaginal canal, placing a sealing element into the vaginal canal, and then allowing the vaginal canal to contract about the sealing element to create the seal. Other variations of **S220** may comprise other manipulations of system variations described above, or any other suitable method of sealing an entrance to the uterus.

Step **S230** recites coupling the suction module to a pump, and functions to prepare the suction module to transmit a negative pressure to the interior of the uterus. Step **S230** may be performed before or after the suction module has been delivered to the interior of the uterus. In one variation, Step **S230** may comprise coupling a connecting tube of the suction module to a clinical suction line, as shown in FIG. **12**, but in other variations, Step **S230** may alternatively comprise coupling any suitable portion of a suction module to any suitable pump element.

Step **S240** recites applying a negative pressure within the uterus upon activation of the pump, and functions to generate a stimulus that enables an atonic uterus to contract, thus counteracting uterine atony. The negative pressure may result in a uniform mechanical stimulus or a non-uniform mechanical stimulus that results in contraction of the uterus to control hemorrhaging. For instance, the negative pressure may be a hydrostatic pressure. In an example, the pump is activated to produce a flow rate of less than 30 liters per minute, and a negative pressure of up to 3 psi within the uterus, while monitoring pressure levels using a pressure sensor.

Step **S250** recites maintaining the negative pressure within the uterus to induce uterine contraction, and functions to facilitate closing of exposed uterine arterioles in the uterine wall. Step **S250** may further function to decrease the possibility of the uterus returning to an atonic state. Preferably, the negative pressure is maintained until hemorrhaging has been reduced to safe levels or has substantially stopped. The negative pressure may also be maintained as long as deemed necessary to maintain the uterine contraction, and in a specific example, is maintained for between 1 and 24 hours. In an example, maintenance of a negative pressure of 3 psi within the uterus causes the uterus to fully contract within 15 seconds. Additionally, Step **S250** may comprise monitoring a patient's blood pressure and heart rate while the negative pressure is maintained, and eliminating the negative pressure after levels have returned to a normal level. In an example, the negative pressure may be eliminated once the patient's systolic blood pressure is between 90 and 140 mm Hg, and the patient's heart rate is between 40 and 100 beats per minute. The negative pressure is preferably eliminated once hemorrhaging has been reduced to safe levels or has substantially

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stopped. The negative pressure may be eliminated by removal of a seal to the entrance to the uterus, which may be performed in any suitable manner (e.g., deflation of an inflatable balloon seal, radial contraction of a membrane, etc.).

As shown in FIG. 11, Step S250 may further comprise Step S255, which recites obstructing a connection between the suction module and the pump. Step S255 functions to maintain a negative pressure within the uterus, even upon deactivation of the pump. Step S255 also functions to prevent premature elimination of a negative pressure within the uterus (e.g., upon deactivation of the pump). Step S255 may further function to allow intrauterine tissue to re-energize, and may further function to facilitate removal of the suction module from the uterus. In one variation, Step S255 may comprise clamping a connecting tube between the suction module and the pump, as shown in FIG. 11. In another variation, the connection may be a valved connection, such that Step S255 comprises shutting a valve to obstruct a connection between the suction module and the pump. Step S255 may, however, comprise any suitable variation of obstructing a connection between the suction module and the pump.

As shown in FIGS. 9 and 10, the method 200 may further comprise Step S260, which recites delivering the suction module into the uterus. Step S260 functions to initiate treatment of an atonic uterus. Preferably, Step S260 comprises delivering the suction end of the suction module described above into the uterus; however, Step S260 may comprise delivering any suitable suction module into the uterus. The reverse of Step S260, as shown in FIG. 11, may comprise removing the suction module from the uterus, and in an example, may comprise clamping a connecting tube to the suction module, deactivating the pump, and then withdrawing the suction module from the uterus. Other variations of Step S260 and the reverse of Step S260 may comprise any other suitable methods of delivering the suction module into the uterus and removing the suction module from the uterus.

As shown in FIGS. 9 and 12, the method 200 may further comprise Step S270, which recites transmitting bodily fluids out of the uterus through the suction module. Step S270 functions to remove fluids from within the uterus in the process of inducing contraction of an atonic uterus. The bodily fluids preferably pass into at least one opening of the suction module and into the connecting tube of the suction module; however, Step S270 may alternatively comprise any other means for transmitting bodily fluids out of the uterus.

Also shown in FIGS. 9 and 12, the method 200 may further comprise Step S280, which recites filtering the bodily fluids. Step S280 functions to prevent unwanted substances from entering the pump, which allows the pump to maintain proper function and to continually apply a negative pressure. Step S280 may further function to enable monitoring of blood loss. For example, filtering the bodily fluids S280 into a transparent container may allow a caretaker to monitor a quantity of blood lost during implementation of the method 100. Step S280 may occur at any point along the suction module, distal to the pump; however, Step S280 preferably occurs along a connecting tube coupled to the pump.

The FIGURES illustrate the architecture, functionality and operation of possible implementations of systems and methods according to preferred embodiments, example configurations, and variations thereof. In this regard, each block in the flowchart or block diagrams may represent a module, segment, or step, which comprises one or more executable instructions for implementing the specified logical function (s). It should also be noted that, in some alternative implementations, the functions noted in the block can occur out of the order noted in the FIGURES. For example, two blocks

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shown in succession may, in fact, be executed substantially concurrently, or the blocks may sometimes be executed in the reverse order, depending upon the functionality involved.

The system and method of the embodiments can be embodied and/or implemented at least in part as a machine configured to receive a computer-readable medium storing computer-readable instructions. The instructions can be executed by computer-executable components integrated with an application, applet, host, server, network, website, communication service, communication interface, hardware/firmware/software elements of a user computer or mobile device, or any suitable combination thereof. Other systems and methods of the embodiments can be embodied and/or implemented at least in part as a machine configured to receive a computer-readable medium storing computer-readable instructions. The instructions can be executed by computer-executable components integrated by computer-executable components integrated with apparatuses and networks of the type described above. The computer-readable medium can be stored on any suitable computer readable media such as RAMs, ROMs, flash memory, EEPROMs, optical devices (CD or DVD), hard drives, floppy drives, or any suitable device. The computer-executable component can be a processor but any suitable dedicated hardware device can (alternatively or additionally) execute the instructions.

As a person skilled in the art will recognize from the previous detailed description and from the figures and claims, modifications and changes can be made to the preferred embodiments of the invention without departing from the scope of this invention defined in the following claims.

We claim:

1. A uterine hemorrhage controlling system comprising:
  - a connecting tube comprising a lumen and further comprising a proximal portion configured to connect to a pump;
  - a suction module configured for insertion into a uterus, the suction module comprising a flexible suction tube configured to form a first loop,
  - a set of openings defined along a medial surface of the first loop of the flexible suction tube, wherein the set of openings is configured to be medially oriented away from an interior surface of the uterus when the suction module is delivered into the uterus, and configured to fluidly connect to the lumen of the connecting tube, and wherein activation of the pump generates a negative pressure at the set of openings to induce uterine contraction about the first loop without obstruction of the set of openings;
  - a shield of unitary construction with the flexible suction tube and configured to limit obstruction of the set of openings; and
  - a seal coupled to the connecting tube between the suction module and the pump and operable in a first configuration, the seal configured to hermetically seal an entrance to the uterus to maintain a negative pressure within the uterus in the first configuration, thereby closing exposed arterioles of the uterus in order to control uterine hemorrhaging, wherein the seal comprises a balloon configured to have an expanded configuration, as the first configuration, and a contracted configuration, as a second configuration.
2. The system of claim 1, wherein the shield is configured to flank a portion of the flexible suction tube and to diverge outward proximal to at least one opening of the set of openings.
3. The system of claim 1, wherein the balloon is physically coextensive with the connecting tube, substantially surrounds

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the connecting tube at a location between the pump and the suction module, and is substantially concentric with the connecting tube.

4. The system of claim 1, wherein the expanded configuration of the balloon produces a balloon diameter substantially between 5 and 14 cm.

5. The system of claim 1, wherein the balloon has a volumetric capacity of up to 300 mL and is configured to withstand an internal pressure of at least 5 psi.

6. The system of claim 1, wherein the seal comprises a membrane coupled to a set of deformable members, angularly displaced about a centerpoint of the membrane, and wherein the set of deformable members is configured to expand the membrane radially into the first configuration and configured to contract the membrane radially into a second configuration.

7. The system of claim 1, wherein an axial deformation of the seal produces a sealing configuration that blocks an entrance to the uterus.

8. The system of claim 1, wherein the shield comprises a second flexible member that is physically coextensive with the flexible suction tube.

9. The system of claim 8, wherein the second flexible member is configured to form a second loop that extends in a wider loop than the first loop and is radially displaced from the first loop.

10. The system of claim 9, wherein the second flexible member is a second flexible suction tube comprising a second set of openings configured to fluidly connect to the lumen of the connecting tube.

11. The system of claim 10, wherein the second set of openings is defined along a medial surface of the second loop of the second flexible suction tube, and wherein the second set of openings is configured to be medially oriented away from an interior surface of the uterus when the suction module is delivered into the uterus.

12. The system of claim 1, wherein the balloon comprises an opening configured to receive at least one of a gas and a fluid that expands the balloon into the expanded configuration.

13. The system of claim 12, wherein the opening is fluidly coupled to a delivery conduit that delivers at least one of a gas and a fluid into the balloon, and wherein the delivery conduit comprises a delivery tube that runs parallel with the connecting tube.

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14. A uterine hemorrhage controlling system comprising: a connecting tube comprising a lumen and further comprising a proximal portion configured to connect to a pump; a suction module configured for insertion into a uterus, the suction module comprising a flexible suction tube configured to form a first loop,

a set of openings defined along a medial surface of the first loop of the flexible suction tube, wherein the set of openings is configured to be medially oriented away from an interior surface of the uterus when the suction module is delivered into the uterus, and configured to fluidly connect to the lumen of the connecting tube, and wherein activation of the pump generates a negative pressure at the set of openings to induce uterine contraction about the first loop without obstruction of the set of openings;

a shield of unitary construction with the flexible suction tube and configured to limit obstruction of the set of openings; and

a seal coupled to the connecting tube between the suction module and the pump and operable in an expanded configuration, the seal configured to hermetically seal an entrance to the uterus to maintain a negative pressure within the uterus in the expanded configuration, thereby closing exposed arterioles of the uterus in order to control uterine hemorrhaging,

wherein the seal comprises a balloon configured to have the expanded configuration and a contracted configuration, the balloon including an opening fluidly coupled to a delivery conduit that runs parallel with the connecting tube and that delivers at least one of a gas and a fluid into the balloon that expands the balloon into the expanded configuration.

15. The system of claim 14, wherein the balloon is physically coextensive with the connecting tube, substantially surrounds the connecting tube at a location between the pump and the suction module, and is substantially concentric with the connecting tube.

16. The system of claim 15, wherein the expanded configuration of the balloon produces a balloon diameter from 5 to 14 cm, and wherein the balloon has a volumetric capacity of up to 300 mL to substantially seal the entrance to the uterus.

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